With GPS, The Future Has Arrived

By David Lewis

The NavStar Global Positioning System, or GPS, represents the ultimate integration of space, computer, and radio technologies. Essentially, GPS can provide extremely accurate position and velocity information very quickly anywhere on Earth. This is accomplished with the use of a group of high-orbiting satellites (the "constellation"), a ground-based control network, and portable and mobile receivers.

Developed and implemented by the U.S. Department of Defense (DOD) at a cost of $10 billion, the primary function of GPS for both military and civilian interests is navigation. Ever since humans have ventured into unknown territory, on land or water, methods of keeping track of where we are and where we are going have been of utmost importance. GPS is revolutionizing navigation in all segments of transportation, threatening other technologies with obsolescence.

If you have not already heard reference to GPS on your scanner, expect to shortly. All types of civil and military services are using GPS routinely to pinpoint locations more precisely than possible with any other method. Airborne firefighters, police officers, paramedics, Coast Guard rescue vessels, armed forces ground and air units, commercial and private pilots—this list is getting longer faster than it can be written.

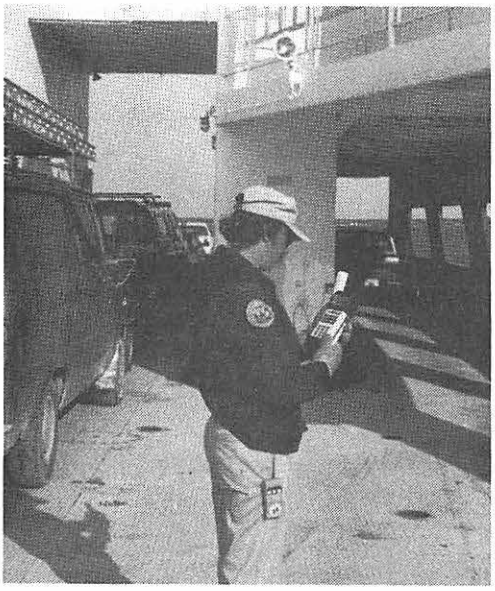
How GPS Works

When completed, the GPS constellation will consist of 24 satellites, 21 continuously operational with three "on-line" spares. Each satellite carries radio transmitters and atomic clocks. The receiver on Earth calculates its position by analyzing the amount of time it takes for transmitted signals to arrive from the different satellites and then triangulating. Each satellite's radio signal consists of a complex code which is precisely synchronized with the other satellite signals. The atomic clocks, known for extreme accuracy, ensure that the signals do remain "in synch."

The transmitted code, known as "pseudo random code," is a long string of digital information which is continuously transmitted and repeated. Each cycle takes one week. A GPS receiver has this code "playing" along in its memory and as the satellite signals are received, incoming codes are sampled and compared to the receiver's reference code. Since radio signals travel at a finite speed, each satellite's signal arrives at a slightly different time and thus the

Lancaster County Engineering Department/GPS World

Global positioning systems are not only used for navigational purposes, but are being used to update land surveys.

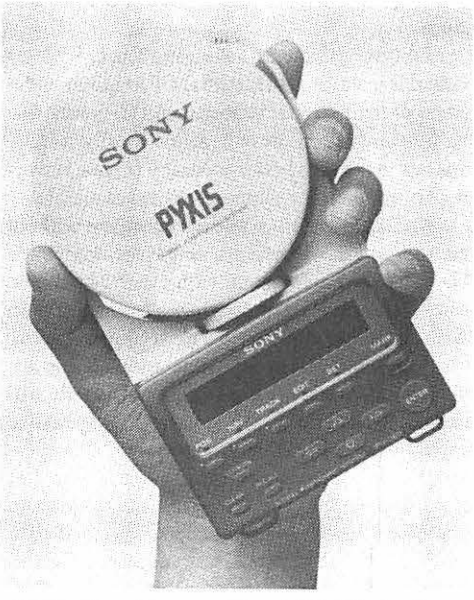


David Lewis

One of the first widespread uses of GPS was for maritime navigation. Pictured is the Margaret Chase Smith Ferry of the Maine State Ferry Service

nodes, "in synch" as they leave the satellites, arrive slightly "out of synch." Microprocessor circuits in the receiver use these minute timing differences to compute the receiver's position relative to each satellite.

The satellites are also continuously transmitting information about their orbital positions. The GPS receiver combines this data with relative position calculations to provide a three



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How May I Use Thee?

Let me count the ways! Last year, *GPS World* magazine (P.O. Box 1965, Marion, OH 43305-2064; 614-382-0886) ran its first annual contest for the most innovative and important applications of GPS technology. The May issue published thirty-two distinct projects which used GPS technology either to do what had never before been possible, or to accomplish tasks in much less time and expense than with previous methods.

Navigation and surveying in difficult terrain such as the Great Barrier Reef in Australia, in the National Forests, or in remote areas of China or the Amazon comprised many of the projects. One prize winner uses GPS to track the location of ambulances that call for helicopter evacuation of severely injured trauma patients, enabling the helicopter to fly directly to the site instead of searching for recognizable landmarks.

Another winning usage involves the measurement of radiation patterns transmitted by television and radio antennas. With GPS a plane can fly in circular paths around the antenna, while antenna signal strength and the plane's position coordinates are being automatically recorded.

Mapping towns in Africa, charting new roads in Papua New Guinea or in environmentally sensitive regions of the U.S., pinpointing targets for data communications, finding lost hikers or soldiers in the deserts of Kuwait, finding a favorite fishing hole... the uses to which GPS has already been put seem endless. Time itself (as in the atomic clocks at WWV) uses GPS to calibrate the exact time. In 1987, AT&T first used the same kind of GPS-referenced timing to synchronize lines for digital telecommunications. Several U.S. airlines are testing GPS for use in navigation and landing systems.

The future has arrived indeed.

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dimensional position (latitude, longitude, and altitude) here on Earth.

The satellites orbit at an altitude of 10,900 miles and one complete orbit takes 12 hours. (For comparison, geo-synchronous communications satellites are over twice as high: 22,500 miles; and take 24 hours to complete their orbit to match the Earth's rotation). GPS satellites are in six orbital planes and are distributed such that at least four of them are "visible" from any point on Earth at all times. At the time of this writing, 19 of them are in orbit and functioning.

How GPS is Used

GPS was designed and built as a military system. The Persian Gulf War saw extensive use of GPS in positioning and navigation on land, at sea, and in the air; it also served as a major component in weapons delivery systems. As a military system it is more than living up to the potential envisioned when development was begun in the late 1970's.

A GPS receiver is most commonly used in combination with ("embedded" in) other electronics circuitry to accomplish a specific task. Consider the hand-held units offered now by several companies. These compact, self-contained receivers are also navigational computers: in addition to providing position information, microprocessor circuitry allows course and speed to be displayed almost instantly. A sequence of intermediate destinations, known as waypoints, can be entered with keystrokes, and the necessary course alterations will be displayed as each waypoint is reached.

Most of the receivers on the market today can be interfaced to an autopilot (on a boat or an aircraft) and make the course changes independent of human control. At any instant the present position, heading, distance, speed, and time remaining to the next waypoint can be displayed. Any deviation (typically caused by wind or current) from the planned route is taken into account and compensated for.

Monitoring GPS

Although GPS satellites don't transmit a signal that can be listened to in the conventional sense, you can monitor the status of the entire system on a shortwave receiver. Tune to WWV, National Bureau of Standards, on 2.5, 5, 10, 15, or 20 MHz at 14 minutes past the hour: you'll hear an update of how many satellites currently are in orbit, and which, if any, are temporarily out of service for testing or maintenance purposes.

You'll also hear their disclaimer that "GPS is not fully operational at this time." The Department of Defense isn't going to consider GPS operational until all of the satellites are in orbit and functioning, despite the fact that the system is actually working quite well for two-dimensional "fixes." Three dimensional coverage will not be reliable for 24 hours a day until all satellites are deployed.

The GPS unit can also be interfaced with a CD-ROM chart display system which shows the navigator his or her position on a chart or map of the area. Quite commonly used on boats now, this type of system is a major emerging technology in automotive design. Imagine the screen on your dashboard with the roadmap displayed with a blinking "you are here" symbol!

While industry experts estimate that 90% of GPS equipment currently in use falls into the marine and aeronautical navigation field, they

The Garmin GPS 50 Personal Navigator component set.

The MotorolaTRAXAR 6-channel GPS Handheld navigator.

predict that within a few years 90% will be in the land mobile industry.

Unbeatable Accuracy

Just how precise is GPS? With a handheld unit costing about $1,400, repeatable accuracy of position within 15 meters (50 feet) can be achieved. This is significantly better performance than is available with LORAN or any other means of positioning. The military versions of GPS receivers, using a protected code not available to their civilian counterparts, provide accuracy of position to 5 meters!

Then there is Differential GPS. This is the segment of GPS technology used by surveyors and cartographers; while not giving instant readouts, differential methods can provide accuracies of less than one centimeter! Thus maps and charts are now being created which are exponentially more detailed and accurate than previous versions.

Longwave listeners take note: The U.S. Coast Guard is installing differential GPS equipment in some of their coastal beacons, and GPS data will be transmitted on these beacons locally to give vessels in the area better accuracy for maneuvering in tight harbor approaches and channels.

A discussion of GPS isn't complete without mentioning the Russian counterpart, known as GLONASS. This system, with 12 of 24 planned satellites currently in use, has a lot in common with GPS despite independent development. Proposals exist and product development is under way to manufacture equipment which will use GLONASS and GPS side by side to realize capabilities greater than either system alone provides. The breakup of the Soviet Union has slowed progress, but in this country efforts to combine the two technologies continue unabated.

Planes, trains, boats, automobiles—GPS is being used in every kind of vehicle imaginable, and is going to be used in ways as yet unimagined. Keep your ears tuned for further developments in this the cutting edge of "high-tech": the Global Positioning System.

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